Chapter 6 Appendix 4
Spill Effectiveness/Efficiency: Scoping the Information
PATH Task 3.1.4a
A. Giorgi (13 June, 1996)

An important smolt passage metric is the proportion of the smolt population that passes each dam via the spillway. At dams lacking bypasses or sluiceways, the spillway is the only non-turbine passage route available. At other dams the contribution of spillway passage to overall non-turbine passage varies according to the passage effectiveness of the bypass or sluiceway systems. Smolt passage rates over spillways can be represented as predictive models, where the % passage is expressed as some function of the proportion of the river flow that is discharged as spill. Alternatively, this measure is often expressed as a ratio of the % of the population spilled to the % total flow discharged as spill. A common assumption in the basin is that the spill efficiency at most dams is approximately 1.0, or fish and water volume passed through the spillway in equal proportions.

Estimating Smolt Passage Proportions Through The Spillway

Hydro-acoustics- Two tools have been used to estimate the proportion of the smolt population passing via spill; hydroacoustics and radio telemetry. By far and away hydroacoustics has been used more frequently. In general, hydroacoustic evaluations deploy transducers across the powerhouse and spillway to estimate the proportion of smolts passing each route. The estimates are not species-specific and represent the composite multi-species population passing the site. During the spring several salmonid species are mixed, whereas in the summer oceantype chinook are the dominant salmonid most of the time. Also, there can be minor contributions from non-salmonid species during select periods.

Several investigations have constructed quantitative models to predict spill effectiveness at varying spill levels; those are summarized (Table 1).

Table C6 A4-1: Spill effectiveness functions derived for Mid-Columbia River dams, using hydro acoustic estimates.

Dam	Model: % spill passage =	Citation
Wells	89%	Skalski (1993)
Rocky Reach	0.66 * %spill	Raemhild et al. (1984)
Rock Island	0.94 * %spill + 11.3	Ransom et al. (1988)
Wanapum	15.42 * ln(%spill)	Dawson et al. (1984)
Priest Rapids	0.82 * ln(%spill)	Dawson et al. (1984)

At Wells Dam the situation is unique in that a vertical slot bypass system is associated with the spillway. Evaluations have revealed that bypass/spill passage remains about constant regardless of the absolute volume discharged as spill. Skalski (1993) used three years of data to estimates the passage rate at Wells Dam.

In all the cited cases (Table 1), confidence limits accompany these predictive models, and they tend to be quite broad (Figure 1). Furthermore, the reported predictive models typically apply to either night or day estimates, which can differ considerably as depicted in Figure 1. However, regression models were not reported for both conditions, usually only scattergrams were provided. Furthermore, spring and summer spill passage estimates usually differ, but separate functions have not been derived for each period. Typically, a spring model has been adopted and applied to both seasons in passage modeling analyses, e.g., CRISP1.5 and SLUSH (a variant of FLUSH configured for the Mid-Columbia and employed in the recent Habitat Conservation Plan process). Perhaps even more importantly, most of the models in Table 1 are dated, and all of the regressions are based on only a single year's sampling. The extent to which the predictive equations are truly representative is questionable.

Since those models were constructed, additional years of hydro-acoustic sampling has occurred at most of those dams. Yet the collective data have not been analyzed in total; models have not been updated. Typically, the annual reports fail to cumulate data and estimates from previous years. Only Steig (1994) has attempted to compile information for all hydro-acoustically monitored dams in both the Snake and Columbia rivers through 1992. In that evaluation estimates were pooled across years and displayed in graphical fashion. He did not derive new regression models. Such a comprehensive analysis remains to be done. However, Steig (1994) did statistically compare spring and summer passage estimates and found no difference between the two seasons. However, the considerable variability apparent at some dam sites may have contributed to poor discriminatory capability. Steig's (1994) paper is attached to this text for the reader's inspection.

I conclude that we have a poor understanding of actual spill effectiveness occurring at dams in the Snake and Columbia rivers. In part this is due to the absence of a comprehensive synthesis analysis of the data and calculated estimates. In my opinion such an effort would be instructive. Within the context of the proposed analysis, the region needs a sound assessment as to whether the resolution of hydro-acoustic data is sufficiently fine to yield representative measures of smolt passage proportions over spillways.

Radio Telemetry- This method has only been used at a few dams for the purpose of evaluating spill passage. Spill passage estimates obtained with radio telemetry are fundamentally different from those based on hydroacoustics in that radio telemetry:

1. Does not provide instantaneous passage estimates, but rather a group response as observed over a period of several days.
2. Does not typically yield a sufficient number of individual passage estimates to construct regression models. Although the new digitally-coded miniaturized tags may offer improved capabilities.
3. Does estimate the mean passage rate and confidence limits for a test population encountering a spill condition/program as implemented over an extended passage period (days to weeks).
4. Does provide species-specific information.

Not surprisingly estimates acquired with the two methods, when taken at the same dam during the same season may not comport. For example, in 1985 both techniques were used at Lower Granite Dam. In 1985, Wilson et al. (1991) using radio-tagged yearling chinook estimated that at spill levels of 20 and 40%, 41 and 61% of the yearling chinook passed through the spillway, respectively. In contrast, that same year Kuehl (1986) monitoring the composite spring smolt population with hydro-acoustics estimated that fish passed over the spillway in the same proportions as the amount of water discharged as spill, e.g., 20% spill yields 20% smolt passage. Since each technique measures different populations over different time frames, the differences should not be unexpected. Nevertheless the question remains as to which measure is most representative and should be incorporated into passage models.
Using radio telemetry to estimate spill passage rates requires:

1. deploying an array of antennas across a dam;
2. releasing groups of tagged smolts well upstream to ensure representative dispersion upon arrival at the dam; and
3. identifying the passage locations at the dam.

A common estimate is the percentage of smolts last detected at the spillway that were detected anywhere across the face of the dam or in the immediate forebay. This approach has been applied at three projects; John Day Dam (Giorgi et al. 1985, Snelling and Schreck 1995), The Dalles Dam (Snelling and Schreck 1995), and Lower Granite Dam (Wilson et al. 1991). Of these studies, spill passage rates for yearling chinook have been estimated and reported by Giorgi et al. (1985) at John Day Dam, and Wilson et al. (1991) at Lower Granite Dam. At John Day Dam, Giorgi et al.(1985) found no significant difference between the % water spilled and the smolt passage rate through the spillway. In contrast, at Lower Granite Dam smolts passed in proportions exceeding the proportion water discharged as spill (Wilson et al. 1991), as described previously. In 1995, NBS investigators again estimated spill passage at Lower Granite Dam, but those results are not yet published.

Conclusions

It is generally assumed and commonly modeled that at most dams in the Snake/Columbia system smolts pass via the spillway in the same proportion as the amount of water discharged as spill. This assumption has not been verified with any sort of comprehensive quantitatively rigorous analyses. Furthermore, existing spill passage regression models may not be representative, since they by-and-large are derived from a single seasons data and either a day or night period separately. Therefore, a thorough synthesis of existing hydroacoustic estimates appears warranted. Even so, the results of such an effort will still have deficiencies or limitations, since the passage estimates will still pertain to a multi-species population, and precision will likely remain poor given the nature of hydroacoustic sampling. Nevertheless, a more realistic foundation can be established from which to judge how instructive future hydroacoustic estimates of spill passage will be. In the context of PATH such a retrospective analysis may involve considerable effort and time. It seems that an analytical team comprised of a biologist, a hydro-acoustician, and a biometrician would be constructive and appropriate. Alternatively, if species-specific estimates are required, the need for a comprehensive synthesis analysis is questionable.

Radio telemetry can provide species-specific estimates of spill passage with estimable variances. However, the studies can be expensive. The value of the information has to be realistically weighted against research cost. Furthermore, depending on the test species, the relatively large tag size can require that the largest individuals in a population be used as test fish, this is particularly true for ocean-type chinook. Additionally, detection probability decreases with increasing fish depth, a situation that may require consideration when interpreting certain passage estimates. Given recent developments in the further miniaturization of digitally-coded tags, opportunities for improving estimates of spill passage may be forthcoming. In 1996, several investigators are experimenting with this new generation of tag. Results from those studies should be instructive in assessing the potential for this tool in spill passage evaluations.

References

Dawson, J., A. Murphy, P. Nealson, P. Tappa, and C. Van Zee. 1984. Hydroacoustic assessment of downstream migrating salmonids at Wanapum and Priest Rapids dams in 1983. Research report from Biosonics, Inc. to Grant County PUD, Ephrata, WA, 23 p., plus appendices.

Giorgi, A. E., L. C. Stuehrenberg, D. R. Miller, and C. W. Sims. 1985. Smolt passage behavior and flow-net relationship in the forebay of John Day Dam. NMFS Coastal Zone and Estuarine Studies Division. Final report to the Bonneville Power Administration. Contract No. DE-A179-84BP39644, 85 p. plus appendices.

Kuehl, S. 1986. Hydroacoustic evaluation of fish collection efficiency at Lower Granite Dam in spring 1985.Final report to USACE, Walla Walla, WA, 106p.

Raemhild, G., T. Steig, R. Riley, and S. Johnston. 1984. Hydroacoustic assessment of downstream migrating salmon and steelhead at Rocky reach Dam in 1983. Biosonics, Inc., Seattle WA.

Ransom, B., G. Raemhild, and T. Steig. 1988. Hydroacoustic evaluation of deep and shallow spill as a bypass mechanism for downstream migrating salmon and steelhead at Rock Island Dam. In Proceedings: Fish Protection at Steam and Hydro Power Plants, EPRI: p. I-70 to I-84.

Skalski, J., 1993. Additional Summaries of 3-year bypass efficiency study at Wells Dam (dated 30 March, 1993). Report to Douglas County PUD, East Wenatchee, WA, 4 p.

Snelling, J. C., and C. B. Schreck. 1993. Movement, distribution, and behavior of juvenile salmonids passing through Columbia and Snake river dams. Oregon Cooperative Fishery Research Unit, Corvallis, Oregon. Annual report prepared for the Bonneville Power Administration. Cooperative Agreement No. 14-16-0009-1576, 53 p. plus appendix.

Steig, T. W. 1994. Review of spring and summer spill effectiveness for juvenile salmon and steelhead at various Columbia and Snake River dams, 1983-1992. 13th International Symposium of the North American Lake Management Society, Seattle, Wa., Nov. 29-Dec.4, 1993. Lake and Reservoir Management 9(1):154-162.

Wilson, J., A. Giorgi, L. Stuehrenberg. 1991. A method for estimating spill effectiveness for passing juvenile salmon and its application at Lower Granite Dam on the Snake River. Can. J. Fish. Aquat. Sci. 48:1872-1876.

Figure C6 A4-1: Spill effectiveness estimates acquired with hydro-acoustics at Priest rapids Dam in 1983. Figures reproduced from Dawson et al. (1984).